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From Kyoto to Paris: Measuring renewable energy policy regimes in Argentina, Brazil, Canada, Mexico and the United States

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ABSTRACT

There are numerous strategies to lower greenhouse gas (GHG) emissions or to mitigate global climate change. One of them is to promote polices for developing renewable energy sources. There has been a growth in such policies but not enough is known about their effectiveness. We use a revised version of Schaffrin et al.'s (2015) Index of Policy Activity (IPA)[1] to examine the historical development (1998–2015) of federal and state/provincial renewable energy policies across five federal countries in the Americas: Argentina, Brazil, Canada, Mexico and the United States. Here the focus is on "policy output," which is defined as a function of policy density and intensity. Policy density is measured by counting the number of policies in each country relating to a particular goal during our time frame, while policy intensity, or the strength the policy has toward meeting specific goals, is measured by summing scores for six indicators: objective, scope, integration, budget, implementation and monitoring. The higher the policy score for a country, the more likely the country will be able to meet its intended goals. Our results show that the U.S. has the densest renewable energy policy output followed by Canada, Mexico, Brazil, and finally Argentina has the least-dense policy output. Overall, Brazil and Canada's renewable energy policies were the most intense, followed by Argentina's and the U.S.'s, with Mexico's policies receiving the lowest intensity scores. These countries differ in how long they have supported renewable energy policies and the levels of government that implement them. These findings show that countries may be spending resources on producing myriad renewable energy policies, but without coordination between different levels of government or a concerted effort to ensure that the policy instruments are effective, those resources may be wasted while GHGs continue to rise. This research contributes to the understanding of how individual federal and state/provincial government make efforts toward implementing or enforcing energy policies to influence long-term policy change.

1. Introduction

When addressing strategies to lower greenhouse gas (GHG) emissions, the energy sector requires the greatest focus. Although emissions from deforestation, biomass burning, agriculture and other land use changes account for 24% of global GHG emissions, energy use accounts for almost all of the rest [1]. Even within these non-energy sectors, only a few countries have accounted for most deforestation in the past several decades (e.g. Indonesia, Brazil, Nigeria) and only these countries can significantly reduce or offset land-use related emissions. Almost all of the remaining GHG emissions come from energy consumption. The energy options to lower or offset these emissions have been identified in the past several decades and include some portfolio of energy efficiency, natural gas, renewable energy technologies and nuclear power [2].

Each energy option for GHG mitigation has strengths and weaknesses. Energy efficiency, e.g., is often lauded as the most cost-effective strategy and works well in the short term, but its emissions reduction

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[1] Schaffrin A., Sewerin S., Seubert S. Toward a comparative measure of climate policy output. Policy Stud. J. (2015) 43, 257–82.

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benefits can be offset by rapid economic growth and the "rebound effect" from increased use following energy cost savings [3]. Nuclear power can provide large-scale baseload power free of air pollution, but also has several serious problems: the risks of reactor accidents and weapons proliferation, the lack of long-term waste disposal repositories for radioactive wastes, life-cycle GHG emissions and high capital investment and decommissioning costs [4]. Natural gas is often promoted as an attractive energy alternative because it is currently low cost where available, it is relatively clean and it has only half the carbon dioxide (CO_2) emissions of coal combustion. However, some critics have argued that these benefits are illusory since the gas production emissions of the more greenhouse potent methane (CH_4), especially from shale formations, may be substantial and much larger than commonly assumed [5].

The final energy option, and the focus of this paper, is renewable energy sources such as wind and solar power, hydroelectricity, geothermal and biomass. Its importance was reflected in Jacobson and Delucchi's [6,7] ambitious, two-part assessment of the potential for a global shift to renewable sources of energy for all purposes by 2050. They used baseline energy demand projections from the U.S. Energy Information Administration. Their plan would require 100% of new energy from renewable energy sources by 2030 and completion of a 100% transition by 2050. The authors did not consider nuclear power[2] or biofuels, concluded that gas was an inferior option and incorporated several assumptions for increased energy efficiency into their studies. They found that wind power could meet 50% of the expected global power demand, 40% could be met by concentrated solar power, solar photovoltaic power plants and rooftop systems and most of the rest by hydroelectric and geothermal power plants. They also found that the (net) cost of providing this 100% energy system conversion to wind, water and solar power would be similar to energy costs today (i.e., based on projected and offset costs and including reduced fuel costs) and the barriers preventing such a conversion are primarily social and political. While this work has many critics, especially on the investment costs, intermittency of renewables and timeframe, we mention it as a thought experiment and point of departure for considering climate and energy policies in detail below [8,9].

We employ a novel comparative policy analysis that allows us to compare policy output across states and provinces and between countries. To do so, Schaffrin et al.'s [10] method, which calculates standardized indicators, is used. By calculating intensity and density scores of renewables, we avoid relying on the subjective assessment of experts about the strength of policies [10]. Our analysis provides a more comprehensive overview than extant studies, such as Tobin et al.'s [11] broad mapping analysis of the six types of mitigation targets among parties to the Paris Agreement, by focusing on the role of policy analysis.

The central research question in this paper is how do we measure the national and subnational policy output of existing renewable energy policies in order to assess how they broadly address climate change? An important corollary is: can such an approach lend itself to a comparative analysis across jurisdictions (in this case, five federal countries in the Americas)? We adapt and apply the Schaffrin et al. [10] Index of Policy Activity (IPA) to measure the long-term development (1998–2015) of federal and state/ provincial renewable energy policies across five federal countries in the Pan American region: Argentina, Brazil, Canada, Mexico and the United States. Policy output is a function of policy density (e.g. the number of policies relating to a particular goal) and policy intensity (e.g. the strength the policy has toward meeting specific goals). The primary reason for selecting the five case studies is we that wanted to compare similar systems (corresponding to Mills's method of differences) [12]. That is that they are the largest countries in the Americas by size and population and they share similar federal political systems. Thus, they each have a history of developing relatively autonomous renewable energy and climate policies at the national and sub-national levels. In this study, the most cause for the policy difference were the varying levels of policy intensity.

In the following section, international agreements and an overview of renewable energy policy making in each country are highlighted while Section 3 reviews the policy mix literature. Section 4 outlines the data and methods used in our analysis and Section 5 presents our findings. In Section 6, we discuss our findings and then provide some broader implication as well as avenues for future research.

2. Background

After several years of failed attempts to negotiate and approve a new treaty on climate change mitigation to follow-up the expiring 1997 Kyoto Protocol to the 1992 United Nations Framework Convention on Climate Change (UNFCCC), the international community finally achieved agreement in December 2015 [13,14].[3] Formally called the Paris Agreement, it was a consensus document reached by almost 200 countries in the long-term quest to reduce climate change. Given the political and diplomatic difficulties of achieving a strong climate treaty, diplomats took a different approach in Paris. Rather than seek a strong, binding treaty with deep cuts for all nations, they focused on consensus for action with recognition of the varying political institutions and cultures worldwide. The result was a focus on "intended nationally determined contributions" (INDCs, also known as NDCs once the Agreement was ratified)—basically pledges toward an international goal of limiting planetary warming to no more than 2 °C above pre-industrial levels—which should be strengthened over time. This resulted in an unusual "bottom up" structure of this treaty, without a binding enforcement mechanism. Renewable energy solutions have been identified as critical to achieving the Paris Agreement's ambitious goals. Part of its attractiveness is the Agreement's bottom-up philosophy, ongoing investment in various renewable industries and its political attractiveness [15].

Domestically, countries have been developing numerous renewable policies between ratification of the Kyoto and Paris agreements. For example, in the United States, the federal renewable electricity production tax credit was renewed and expanded as was the vast majority of state governments' approved renewable portfolio standards. In Canada, federal and provincial renewable energy incentives were approved and feed-in tariffs were introduced [16]. However, climate change mitigation was not necessarily a central policy goal in fostering renewable energy policy development; instead, broad energy self-sufficiency goals was the focus of these policies and instruments [17]. However, as countries seek innovative ways to fulfill their Paris NDCs, renewable energy policies will become increasingly vital. In the next section, we review the literature as it relates to how others have measured such policy mixes in the energy sector.

3. Measuring policy mixes and the energy sector: a literature review

With the increasing scholarly interest in renewable energy policy research, there is growing policy-analysis related literature. Most of the analysis has been case studies, often focusing on particular policy instruments or programs such as feed-in tariff, auction or regulation, and often within a particular country (for case studies in the Americas, see Aslani and Wong [18], Bakhtyar et al. [19], Díez Rodríguez et al. [20], Elizondo et al. [21], Liu et al. [22]). Comparative policy research in this

[2] It is noteworthy that only a few countries are aggressively pursuing nuclear power today, namely China, Russia, India and the United Arab Emirates.

[3] A minor amendment to the Kyoto Protocol (the Doha Amendment) was agreed to in 2012. The Doha Amendment set binding GHG emission reduction requirements on the European Union and its member states, but only eight other countries [69].

field has been limited [23,24]. Schaffrin et al. [10] also note that little attention has been paid to policy activity, specifically observable government actions. Schaffrin et al.'s [10] Index of Policy Activity (IPA) borrows from several strands of historical institutional research in the policy field inspired in part by Howlett and Cashore's [25] idea of policy mixes. They suggest that policy mixes are common "multi-level, nested phenomena," where design and instrument selection "are all about constrained efforts to match goals and expectations both within and across categories of policy elements" [25]. The components of such mixes—goals, instruments and calibrations—include policy goals and policy means at various levels of generality [25–27]. This type of multi-tiered policy is also quite common in energy policy making [27], but the cross-sectoral and long-term nature of policy making in the renewable energy sector poses challenges for standard models of policy change that were developed in single-sector contexts and over much shorter time horizons [28].

The number of renewable energy policies that a country uses toward a specific goal only tells part of the story about how well it will be able to achieve those goals. Simply adding up various policy instruments is subject to measurement error because the content of such policies is unaccounted for. More comprehensive policy output analysis can be measured by calculating policy density and intensity. Policy density is measured by an accounting of the number of policies and instruments employed within a policy field, whereas intensity refers to the "strictness or generosity of policies" ([29], p. 33). This includes such factors as the level of involvement, scope and conditions of enforcement, administrative capacity and the procedural features for participation [30]. Schaffrin et al. [10] operationalize policy density by considering the resources, effort and activity invested in a policy throughout the policy process. Specifically, they consider the objectives, scope, integration, budget, implementation and monitoring efforts. Based on expert reviews of 175 climate change policies, Schaffrin et al. [10] developed policy density and intensity indices. Recently, Fleig et al. [31], Ji and Darnall [32] and Bondarouk and Mastenbroek [33] have adopted similar approaches in their policy output studies. These studies have focused their analysis at the national level with no consideration of subnational policy activity or the nature of federal states.

The policy activity we are interested in is the sum of policy density (e.g. the number of policies implemented, superseded or ended which relate to a particular goal) and intensity (e.g. the strength the policy has toward meeting specific goals, measured by six indicators), as developed and validated by Schaffrin et al. [10]. The first intensity indicator, *objectives*, measures the degree, from 0 to 1, to which the policy's goal includes specific targets to help the policy perform effectively. The *scope* indicator measures how many sectors and energy types are targeted by the policy. The next indicator, *integration*, measures the extent to which the policy is part of a larger package of policies. The *budget* indicator reveals the public expenditure relating to the policy. The actors, rules, procedures and sanctions that are outlined are tallied in the *implementation* indicator. Finally, the *monitoring* indicator measures if there is a monitoring plan for the policy and if someone is tasked with monitoring the activities and responsibilities as outlined in the policy. The higher the policy score for a country, the more likely the country will be able to meet its intended goals [34]. The next section reviews how we used Schaffrin et al.'s [10] framework to measure the national and subnational policy output of existing renewable energy policies in five Pan-American countries.

4. Data and methods

In order to calculate an "Index of Renewable Policy Activity" closely corresponding to the Schaffrin et al. [10] IPA, a database of federal and state/ provincial renewable energy policies in Argentina, Brazil, Canada, Mexico and the U.S. from 1998 to 2015 was developed. The year 1998 was chosen as the first year in our analysis because the Kyoto Protocol was adopted in December 1997, marking the beginning of a global agreement that greenhouse gas emissions need to be reduced [35]. We chose the end year, 2015, because it marked the year that the Paris Agreement was adopted by consensus [36].

The International Renewable Energy Agency (IRENA) policy database was the primary source of renewable energy polices in our study. The policies we include in our database follow Howlett and Cashore's [25] concept of policy output, referring to the actions of governments, or their decisions to change or maintain the legislative status quo. In each policy entry, a brief overview of the policy was provided with an up-to-date weblink to detailed policy information, which the authors consulted. Moreover, we consulted with government websites and our co-authors who are renewable energy experts in their respective countries in order to confirm the completeness of our database. We modified Schaffrin et al.'s [10] calculation by measuring each renewable energy policy as a whole (e.g. a policy mix bundle), rather than break them down into their individual policy instruments. The rationale for this approach was that many renewable energy policy instruments were often combined in one policy thus making analysis of their individual intensity and density scores impossible to assess.

We are confident that we captured all relevant policies in our analysis because we worked with our co-authors who are policy and legal experts, who are familiar with these types of policies, and who were able to fill in the necessary missing information from their own experiences with the policies. For example, the list of all relevant policies was checked with representatives of the Ministry of Environment and Sustainable Development of the Argentine nation, the Brazilian Coordinator of the Research Group on Bioenergy at the Institute of Energy and Environment of the University of São Paulo, as well as with experts who have experience working on environmental and energy issues in Canada, Mexico and the U.S. (all of our co-authors). By employing this extensive and exhaustive approach, we are confident that nearly all, if not all of the renewable policies were included in the analysis.

The initial search resulted in 199 policies. Of these, 17 were removed because they were not formulated and implemented during the 1998–2015 Kyoto-Paris period and or failed to focus on renewable energy. Specifically, policies formulated before 1998 but in effect during the 1998–2015 period were excluded. However, if policies were passed and superseded or ended during in our time period, they were included.

The policy density for each country was calculated by summing the number of policies implemented, ended or superseded each year in our 1998–2015 timeframe. Policy intensity (e.g. the strength the policy has toward meeting specific goals, measured by six indicators) was calculated by scoring each policy's objectives, scope, integration, budget, implementation and monitoring according to the rules outlined in Table 1. Two of the authors scored these six components in a two-step process similar to Schaffrin et al.'s [10]: first individually and then each author's scoring was compared for discrepancies. When discrepancies existed, the policy documents were jointly reviewed and a mutually agreed upon score was adjudicated. The averages for each of the six indicator scores for each policy were calculated and those values became the yearly score for the policy. Country's yearly scores were calculated by summing the intensity scores for that year per Schaffrin et al.'s [10] methodology.

5. Findings

5.1. Policy density

Our results show that for the 18-year analysis period, overall the U.S. has the densest renewable energy policy output with 81 policies (60 in-force policies, 10 superseded and 11 ended during the time period), followed by Canada with 50 (28 in-force, 12 superseded and 10 ended), Mexico with 22 (20 in-force and 2 ended policies), Brazil with 16 (14 in-force, 1 superseded and 1 ended) and Argentina with 13 (9 in-

Table 1
Climate policy intensity measures, coding scheme and aggregation rules.
Adapted from Schaffrin et al. [10].

Intensity Measure	Coding Question	Coding Values	Specific Aggregation to Final Value	Range
Objectives	What is the policy objective with respect to policy performance?	0 = no GHG emission reduction target given; .5 = indirect target given (e.g. % biofuel production given); .75 = directly targets climate, but no specific % given; 1 = any % reduction in GHG emissions reduction target		0, .5, .75, 1
Scope	Does the policy include branches of both supply and demand side? Are all mitigation actions targeted?	0 = only one group targeted; .16 = for each additional target group (households, companies, demand or supply); .5 = all groups targeted 0 = only one mitigation action targeted; .05 = for each additional action out of solar, wind, hydro, biomass and other (e.g. geothermal)	Additive aggregation	0-1
Integration	Is the policy integrated in a climate change or renewable energy package or any reference to other policy instruments? Is framework policy included?	0 = no; .5 = yes; 1 = yes, including framework policy		0, .5, 1
Budget	What are the set expenditures of the policy instrument?	0 = no budget given; .5 = general budget is mentioned, but no specific $ amount given; 1 = budget given as specific $ amount	The values of intensity if calculated as the share of the public expenditure or imposition for the policy instrument on total public expenditure for energy and fuels or direct public revenue from the revenues of the value added tax (0-1)	0, .5, 1
Implementation	Is there a statement about implementation procedures specifically allocating actors and rules? How is this implementation planned and is there sanctioning?	0 = no statement about implementation procedures found; .25 = implementation is specifically allocated to actors and rules; .25 = only one specific actor coordinated implementation .25 = implementation procedure is strict in the sense that it does not allow a range or change in standards or rules; .25 = there is sanctioning for actors not complying to the implementation procedure	Additive aggregation	0-1
Monitoring	Is there a specific monitoring process for the policy instrument and by whom?	0 = no monitoring; .5 = monitoring by the implementing agency; 1 = a special external group/ institution is established for monitoring		0, .5, 1

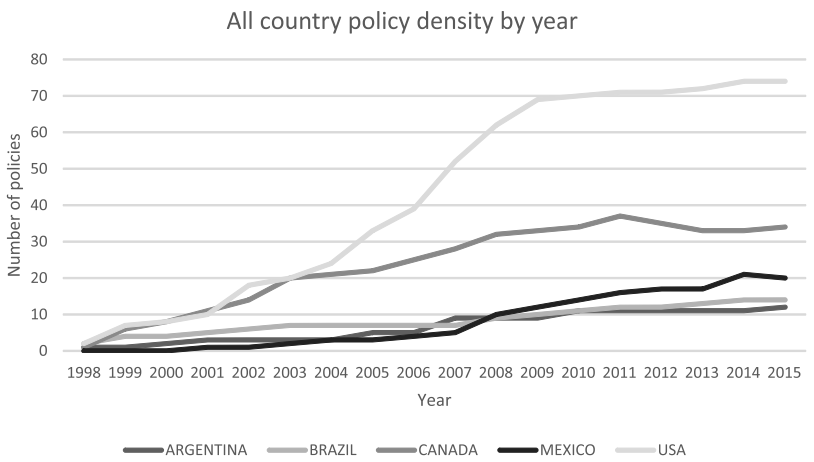

Fig. 1. Policy Density by Country (total number of policies).

force policies, 3 superseded and 1 ended). Fig. 1 shows the cumulative number of policies implemented, superseded or ended each year in all countries over the time period.

The majority of the policies analyzed across countries (118 of 182 total) were federal policies compared to 64 at the state/ provincial level (Fig. 2). In the U.S. a small majority of renewable polices were found at the state level.

5.2. Policy intensity

Figs. 3–5 show the cumulative intensity scores for each country, year by year.

Overall, Brazil's and Canada's renewable energy policies were found to be the most intense, followed by Argentina's and the U.S.'s, with Mexico's policies receiving the lowest average policy intensity scores (Table 2). Each country presented high total intensities in specific indicators. Argentina's policies were the most intense in terms of its renewable energy and GHG reduction objectives and integration; policy implementation and monitoring indicator scores were most intense in Brazil; Canada's renewable energy policies by far had the highest intensity for its budget indicator; and the scope of renewable energy policies and the integration indicator were strongest in the U.S. in terms of intensity. The following section discusses these findings.

6. Discussion

In the case of climate change policies, states and provinces have taken a leading role, especially in the absence of federal government leadership in the U.S. [37,38] or the constitutional authority of provinces in a decentralized federation like Canada [39] or Brazil [40]. In the case of U.S. renewable energy policies, Rabe [41] notes that the states have led efforts to develop renewable energy portfolios. Our research focuses on renewable energy policies in part because despite the Paris Agreement's focus on climate change mitigation as a key goal, some countries do not have the political will or support to enact climate change-related policies, though renewable energy development is supported. This is so because such policies can be supported for other reasons, such as their potential to decentralize energy systems, meet state/ provincial renewable portfolio standards or for their investment opportunities in promising new technologies.

6.1. Policy density

Over the 18 years analyzed, the U.S. and Canada had the highest density scores. Looking only at state or provincial policy density, it is not surprising that the U.S., with more states than any other country in this study, had the greatest number of policies at the sub-government level. Upon closer inspection, Canada's ten provinces were responsible for creating 18 policies, whereas the U.S., with 50 states, produced just 44 policies. Thus, at the sub-national level, Canada has a higher proportional policy output than the United States.

Canada and the U.S. have developed a balanced number of renewable energy policies at both the national and sub-national levels. Federal agencies such as the U.S. Department of Agriculture (USDA) and U.S. Department of Energy (DOE) are also working on developing programs that are not explicitly related to the Paris Agreement or climate change, but that will also help reduce GHG emissions. For example, only a week after Trump announced that he would withdraw the

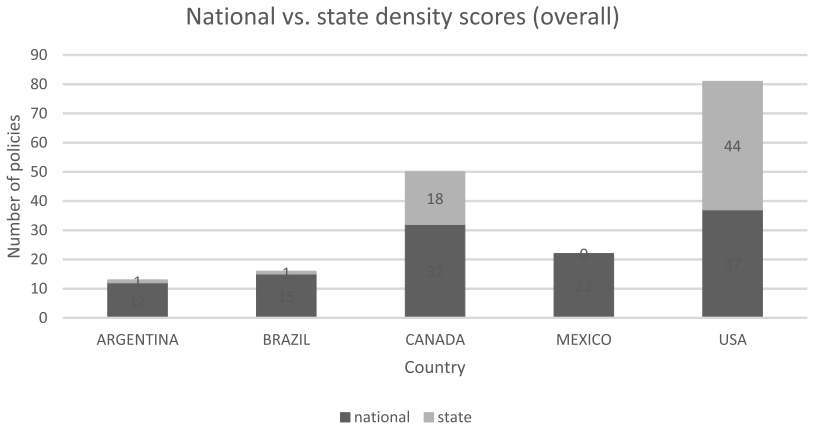

Fig. 2. Number of National and State/Provincial Renewable Energy Policies Created Each Year, 1998–2015.

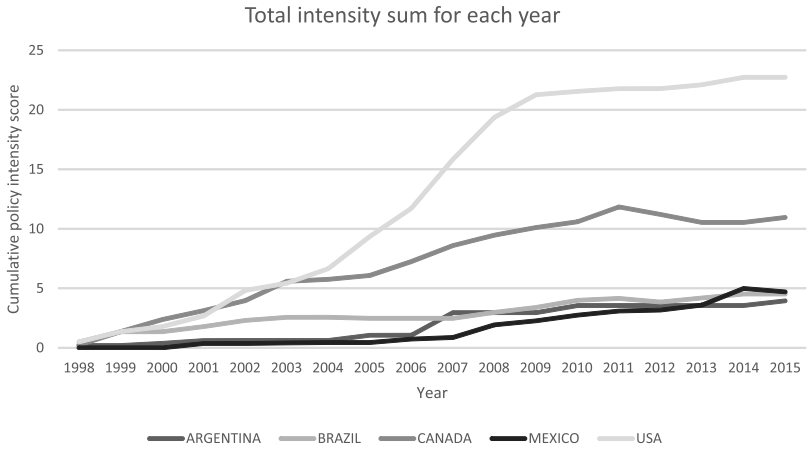

Fig. 3. Total Renewable Energy Policy Intensity Scores by Country, 1998–2015.

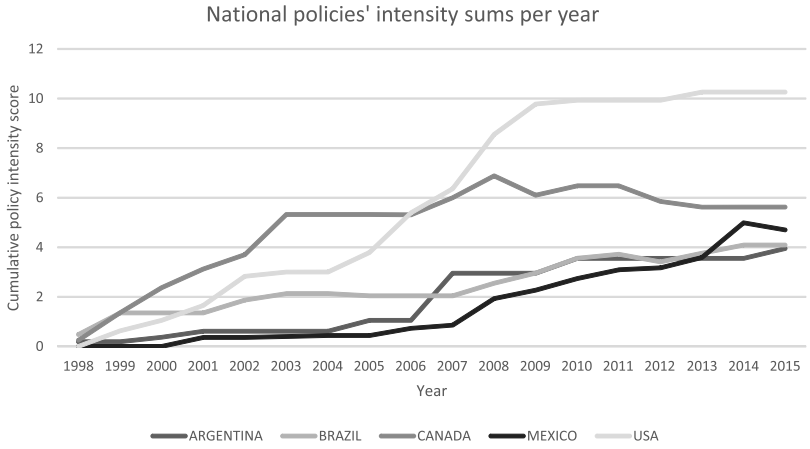

Fig. 4. National Renewable Energy Policy Intensity Scores by Country, 1998–2015.

U.S. from the Paris Agreement, the USDA and DOE announced multi-million-dollar funding specifically for a biomass research program under the Energy Policy Act of 2005 [42]. At the state and provincial level, the U.S.'s individual state Renewable Portfolio Standards and Canada's New Brunswick Energy Blueprint exemplify the broad objectives that policy making at this level covers, including environmental protection, energy independence and economic security. Some states and provinces (the U.S.'s California, Maryland and New York and Canada's New Brunswick, Nova Scotia and Ontario) are clearly more active in renewable energy policy making than others and are responsible for multiple policies, which often target various government sectors.

Despite the federal nature of the governments in each country, the three Latin American countries do not display multi-level governance in practice. The lack of integrated strategies between different levels of government may lead to policy incongruence, which occurs when an otherwise consistent mix of instruments fail to support the overall policy goals [43]. Such incongruence may be inevitable due to constitutional jurisdiction. For example, in Canada, although the federal government has been playing a role in regulating electricity generation and providing funding for renewable energy programs nationwide, provinces that control public Crown land create and implement natural resource policies [44,45].

Mexico had the densest policy output of any Latin American country. The country's domestic renewable energy policies are determined and coordinated by the federal government in a top-down structure. Federal laws dictate what sectorial plans are created, which determine what happens at the local level [46]. For example, the federal government directs biofuel programs and policy creation at the departmental level (the agriculture and rural development sector [SAGARPA], energy sector [SENER] and environmental sector [SEMARNAT and CONAFOR]), creates state-directed policy networks, and also includes professional networks (the state collaborates with academic institutions [47]). Combined, these six federal departments have local state branches that collaborate with academic institutions and research bodies, creating the largest number of political actors on the ground in Mexico. The majority of these state-directed policy networks are centered around and controlled by the federal government, explaining the few policies created at the state-level, as indicated by our policy density results.

Argentina's and Brazil's policies were found to be least dense. Consider Brazil's experience with renewables: its use of renewable energy accounts for almost half of the total energy consumption. As part of Brazil's long-term plan to reduce GHGs through promotion of renewable energy, it has focused on producing biofuels and creating climate change policies at the federal level. Proálcool, the 1975 Brazilian Alcohol Program, promotes the production of ethanol to meet internal and external demand. It has had a high percentage of hydroelectricity and biofuels in its energy mix since the 1970s. Perhaps Brazil's past experience with renewable energy policies before the time period we consider in the paper has enabled more action being taken to reduce GHG emissions, but which do not appear in the policies for the years included in this analysis.[4] Likewise, in the late 1990s, Argentina

[4] Brazil has just approved the so-called RENOVABIO (2017–18), a cap and trade program to reduce carbon emissions which aims to achieve the targets from the Paris Agreement (but is not included in the time period analyzed here)

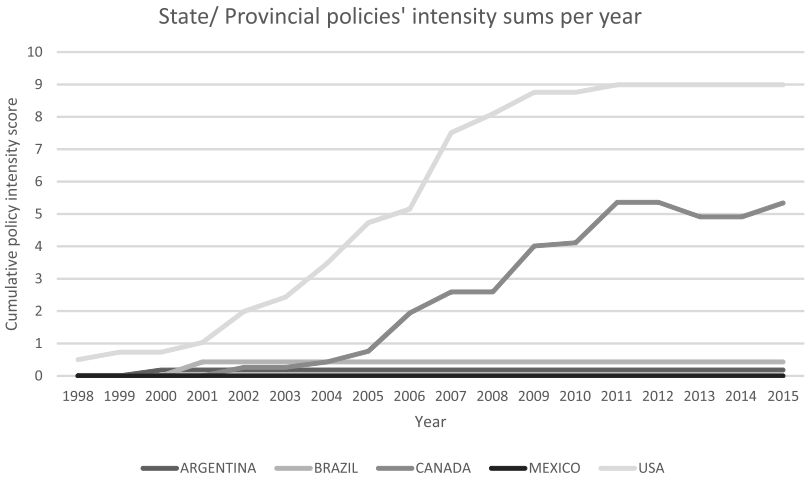

Fig. 5. State/Provincial Renewable Energy Policy Intensity Scores by Country, 1998–2015.

Table 2
Renewable Energy Policy Intensity Indicator Scores by Country, 1998–2015.

	Objectives	Scope	Integration	Budget	Implementation	Monitoring	Average indicator score
Argentina	**0.37**	0.22	**0.23**	0.42	0.46	0.12	0.30
Brazil	0.23	0.22	0.16	0.28	**0.55**	**0.56**	**0.33**
Canada	0.33	0.23	0.13	**0.83**	0.21	0.15	0.31
Mexico	0.18	0.11	0.20	0.30	0.39	0.18	0.23
USA	0.17	**0.28**	**0.23**	0.31	0.52	0.30	0.30

Highest intensity scores for each measure are shown in bold text.

ventured into renewable energy production with the promotion of wind and solar energies through feed-in tariffs, which anticipated the payment of an additional remuneration per kWh of wind and solar energy generated [48]. Such a system, however, failed due to the freezing of electricity prices after the severe economic crisis of 2001 [49].

The number of policies a country has enacted in any one year can help inform us of the historical moments when there was political will and/or authority figures who were interested in mitigating climate change or reducing federal and/or state/provincial GHG emissions. This can help us recognize what type of political environment or national context is best for implementing renewable energy policies. With the enactment of Argentina's Renewable Energy Law 26.190 [50] in 2007, Argentina declared that the production of electricity from renewable energy sources is a matter of national interest [51] and approved imposing a mandatory percentage of bioethanol and biodiesel to be included in the sales of gasoline and diesel at the national level [52]. This law helps explain the growth in the country's density score in 2007 (and a flurry of other related, supportive policies). However, like prior policies, the 2009 Renewable Generation Program, which aimed to generate a market mechanism by setting a subsidized price for the purchase of a maximum amount of energy from renewable sources, the program did not guarantee meeting the norm's goals. As the continuity of the markets fell, it was a victim of the questions that some have about legal security in Argentina [49].

The state of a nation's economy or foreign policy can also explain why there might have been more or fewer renewable energy policies at any given time. For example, with the U.S. shale gas boom since the late 2000s (coupled with hydraulic fracturing technology), natural gas prices dropped and led to more oil and coal use in other countries, displacing renewable energy that might have been consumed instead [53]. This renewed focus on incentivizing U.S. shale gas drilling instead of renewable energy could explain the severe drop off in the number of renewable energy policies late in the 2000s in that country. Conversely, in Canada, one of the most ambitious undertakings to increase renewable energy occurred when the Ontario provincial government introduced the Environmental Protection Act: Ontario Regulation 496/07 Cessation of Coal Use, which required that Ontario Power Generation phase out coal use for electricity produce after December 31, 2014 [16]. In response, the Provincial government passed The Green Energy and Green Economy Act, 2009 and implemented a feed-in tariff program to offset the expected shortfall of coal generated power [16].

6.2. Policy intensity

The higher the intensity score, the more likely the policies will meet their goals [10]. Weak, ineffective policies will most likely be incapable of meeting proposed goals. According to our intensity results, Brazil and Canada's policies were the most intense compared to other countries in this analysis; however, the countries' overall intensity scores were all very similar. By breaking the intensity scores into their respective indicators (e.g. objectives, scope, integration, budget, implementation and monitoring), we are able to see which country scored highest on which particular indicator, revealing that country's emphasis or strength in renewable energy policy making. Each country, with the exception of Mexico, had one area where it had the highest score in one or more measures (see Table 2).

Argentina accounted for the highest objective and integration (along with the U.S.) intensity scores. In addition, its budget intensity score was the second highest behind Canada. Still, these scores were low compared to the maximum possible values that these intensity measures could receive.

About half of Brazil's intensity indicator scores were moderate, while the other indicators were more intense and resulted in the highest overall intensity score of the five countries included in the analysis.

(*footnote continued*)
(see https://www.spglobal.com/platts/en/market-insights/latest-news/agriculture/031618-brazils-renovabio-decree-sets-governance-for-program-official-gazette).

Brazil may be aiming at an ambitious percentage reduction in GHGs with the hope that the country would strive to meet more of its goals than it would if it set the target lower. The longer history of renewable energy usage in Brazil might explain the high intensity scores for implementation and monitoring, the highest of any indicator scores for the countries we included in our analysis. Such measures may have been institutionalized through hydroelectric power and biofuel production over time.

Canada received the second-highest intensity score overall. Compared to the other four countries, Canada has the most intense budget intensity score. The country's second-highest objectives indicator score indicates that the country's renewable energy policies are more often linked to mitigating or reducing GHG emissions than other countries' policies are. The higher scores for the budget measure show that more of the country's renewable energy policies include a budget. At the national level in Canada, Natural Resources Canada (NRCan) has developed several key programs and policies and under Trudeau's Liberal government: $126 million in funding for renewable energy policy and program development was announced in 2016 [44].

Mexico scored low on all policy intensity measures. Most of Mexico's policies promote the growth of renewable energy indirectly as a means to reduce GHG emissions and meet climate change mitigation goals. Mexico has been an invested participant in the global dialogue on climate change through its pledges to mitigate climate change from multiple angles: Mexico was a signatory to the UNFCCC, joined the Conference of the Parties (COP) to the Kyoto Protocol in 2000 and was one of the first developing countries that pledged to reduce GHG emissions voluntarily [54,55]. However, where renewable energy is mentioned in policy documents, it is often tacked onto a list of potential ways for meeting climate change goals rather than meeting renewable energy targets. This might explain the low scope and integration scores. The exceptions are the wind, solar and geothermal laws, which focus specifically on these renewables as a way to diversify the energy sector as domestic petroleum production declines and energy demand increases [56]. The majority of the policies focus on the desired energy outcomes and not on social or environmental criteria. Moreover, these policies can only be considered as guidelines, not policy mandates.

In terms of its intensity measure for policy budgets, Mexico had a fairly weak score, ranking just above Brazil. The federal government funds many of its initiatives with money from public-private partnerships and, in lieu of federal financial support that was once doled out to all states, awards grant money to subnational governments to enact public service programs that the federal government once provided [57]. States and municipal governments can apply for clean development mechanism funding for projects that meet carbon emissions reduction goals and support from international strategies, but these projects are often supported by foreign entities rather than the Mexican government [54]. In the past, Mexican politicians have done a poor job of governing transparently and of holding agencies accountable for achieving their goals [58,54]. The inability of the president to legislate new policy is a major challenge to implementation of climate policy [59]. Thus, unlike the U.S., although the country has the political will to enact climate policies, the governmental structure and lack of capacity to implement and enforce them is weak.

The U.S.'s intensity scores ranged from very high (its mean implementation measure, 0.52) to very low (it scored lower than other countries on the objectives measure, 0.17), with a relatively moderate overall mean score. These varied scores perhaps reflect the country's uneven history of renewable energy and climate policy making. The U.S. signed and ratified the UNFCCC and signed though did not ratify the Kyoto Protocol. While refusing to submit the Kyoto Protocol to the Senate for ratification, President George W. Bush announced a modest climate change strategy in 2002 to reduce GHG emissions. This policy was also ineffective, given his emphasis on domestic fossil fuel development and hostility to climate policy [60]. Bush did sign the Energy Independence and Security Act (EISA) in 2007 [62,63]. President Obama, for his part, used a series of executive and regulatory actions on climate change, including the issuance of the Clean Power Plan by the Environmental Protection Agency in 2014–2015 [64].

The individual and overall intensity measures for each country are low compared to the maximum possible score that each policy could have received (see Table 1). All measures could receive a maximum score of 1, but most policy average intensity scores are below 0.50. This means that each of the countries included could do more to strengthen the intensity and robustness of their policies.

7. Implications and future research directions

Calculating the policy output of a country can provide a broad, big-picture snapshot of policy making activity, but it does not capture incremental changes or feedbacks that occur. In our dataset, we built from the existing online IRENA database, which provides five policy status categories: planned, under review, in force, superseded or ended (we are interested in the latter three here). In our analysis, we do not consider nuanced policy dismantling efforts (such as decreases in budgets, politicians' inaction, by default or their perceived costs of acting) and instead focus on full dismantling (superseding or ending of) programs because, methodologically, it is much easier to collect information on the latter. When looking at a policy area across multiple countries, information such as budgetary constraints or windows of opportunity are difficult to measure or perceive and consistent availability of such data is often lacking.

Furthermore, what does the number of superseded policies a country has say about that country's renewable energy policy making? The U.S. had the highest percentage of policies in our database that had been superseded within the time period studied. Does this mean that the country prefers to incrementally improve policies, building on past successes? Or does it mean that it more often phases out policies and replaces them? Part of the problem is that IRENA does not describe how they determine which label to assign a policy.

In Mexico and Brazil, where federal-level policies are often rewritten with every new president, it is also difficult to determine which components of past policies remain after new national plans are established and policies rewritten. In our dataset, Brazil and Mexico only had one policy between them (one in Brazil) that was superseded. In this type of situation, it seems that one national plan would supersede another, but does that imply that much of the rules, implementation and enforcement stay the same, or should replacement of policies in a national plan be categorized as "ended" policies? Since incoming administrations in these two countries often write national plans that replace the previous administration's plan (and replace employees in government agencies), in these cases, many policies included in the old plan are ended and new policies are implemented. It is possible for future scholars to test this hypothesis by calculating the policy density and intensity for all policies in national plans for two different administrations and comparing the results (yet this would not help determine what the best categorical label should be used for the policies).

In addition to the academic value added, the policy output index should be an important contribution specific to the renewable energy policy analysis field. The methods outlined previously can be readily replicated by governments or stakeholders, allowing them to develop their own custom indices that will lead to the development of improved benchmarking and performance measurement [65]. Over the course of preparing this manuscript, the political climate in Brazil and the United States has significantly changed. The new president of Brazil, Jair Bolsonaro, has not yet defined what will be the next policies related to Brazil's commitment to climate and renewable energy. In the case of the Trump administration in the U.S., new policies aimed at boosting the coal industry, tariffs on solar energy panels and the announced withdrawal from the Paris Agreement signal, at the federal level, the possibility that the density and intensity of renewable energy policies will decline. Despite the political uncertainty, the calculation of policy

output indices is a policy appraisal tool that should be critical for intelligence gathering regardless of political masters. However, even this seemingly benign type of information may not be amenable to speaking truth to power in the current environment. For example, the U.S. Environmental Protection Agency has been "scrubbing" its website of references to climate change.

Nevertheless, the federal nature of the five Pan-American case studies may result in an uptake of our methods in other jurisdictions. Since the 2016 U.S. presidential election, large progressive Democratic states, most notably California and New York, have been pursuing aggressive renewable energy policies. Evidence from studies of Canadian federal and provincial policy analysists found that policy appraisal was their most frequently undertaken task [66]. This is particularly germane because recently Natural Resources Canada has been collecting information regarding its progress in achieving the UN Sustainable Goal 7—"Affordable and clean energy"—and specifically Target 7.2, substantially increasing the share of renewable energy in the global energy mix by 2030. Other agencies have been working to formulate a new Federal Sustainable Development Strategy where the relevance and impact of policies are being assessed. Despite the optimism at the federal level, the Canadian province of Ontario, which was described earlier as a leader in clean energy, recently elected the Conservative party of Doug Ford. One of Ford's first initiatives was to begin a rollback of the previous administration's renewable energy policies. Even so, Canada's federal government is still strongly supportive of renewable energy policy making and its climate commitments. This is evident in its leadership in initiating the Pan-Canadian Framework on Clean Growth and Climate Change which contains numerous strategic directions for renewable energy. Another example is the Energy and Mines Ministers' Conference where federal and provincial ministers responsible for energy and mining portfolios meet annually to discuss a host of policy-specific issues. Such a forum would lend itself to using energy policy analysis such as ours toward developing more effective policy.

Our analysis included only those policies in force during the 1998–2015 period. The richness of the data available lends itself to examining policy legacies prior to the Paris Agreement. Policies that endure over time are likely to influence long-term policy change via policy drift, conversion or layering [67]. This research lends itself to understanding the efforts of each individual federal and state or provincial government that they put toward implementing or enforcing these energy policies. This type of future research will be critical for explaining the variation across states or provinces in any one country. We realize the unevenness of renewable policy activity within countries: some states may boost the policy density and intensity scores (e.g. California, U.S.) while places with significant natural resource extraction (e.g. oil sands in Alberta, Canada) contribute fewer, if any, such policies. Although this research provides only a static snapshot of each country's renewable energy policies, it may supplement analyses focused on political relationships or policy making processes.

This paper provides tangible evidence for those in the climate change policy community (e.g. the United Nations and the UNFCCC) regarding the importance of policy output. Moreover, we have provided a blueprint for the replication of these methods that can be undertaken by other scholars but also by policy analysts working in climate change agencies. Finally, this analysis enriches the recent contributions to energy policy mix literature by testing some of its core theoretical assumptions.

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Declarations of interest

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